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ABSTRACT

This paper provides an evaluative framework to clarify the similarities and differences in five purposes for which a computer may be used to aid instruction. Each purpose implies its own method of evaluation and each has a different set of effectiveness measures that highlight its unique value. The first four involve adding new skills or knowledge to the instructional process, or what is called "value added" computer use: while the fifth deals directly with cost effectiveness. The five purposes are (1) computing opportunities--providing facilities for each school: (2) computer literacy--learning what "computer" means: (3) curriculum enhancement--attaining new objectives: (4) educational reform, e.g., high school education at home: and (5) cost effectiveness, e.g., comparison of two ways of learning English grammar. Measures of effectiveness for each of these purposes are discussed in detail. A final item considers the process by which one can decide when to use cost effectiveness judgments in contrast to value added judgments in comparing computers or any other innovation in instruction. (RAA)

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PREFATORY NOTE

Earlier versions of this paper were presented as invited addresses at the Carolina Conference on Computer-Assisted Instruction, University of North Carolina at Ashville (May 15, 1978), and at a conference of the Association for Educational Data Systems (May 19, 1978) in Atlanta, Ga.

A popularized and abbreviated version of this paper has also been published, under the same title, in the March 1980 issue of *Phi Delta Kappan* magazine.

The author gratefully acknowledges the assistance of his colleague, Mrs. Beverly Hunter, in formulating the framework of computing purposes described herein. He has also benefited from reviews by Drs. Harold F. O'Neil, Harold Wagner, Saul Lavisky, and the late William A. McClelland.

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IT'S 1980:
DO YOU KNOW WHERE YOUR COMPUTER IS?

Robert J. Seidel, PhD

Introduction

The use of computers in academic institutions has been increasing at all levels over the past decade.[1] For example, almost three-fifths of all secondary schools were actively using computers in 1975, in contrast to one-third in 1970.[2] Federal funding support from the U.S. Office of Education and the National Science Foundation has totaled $230 million since 1965.[3] In October 1977, a House of Representatives subcommittee of the Committee on Science and Technology[4] held hearings to review ". . . the role computers have played in the past in aiding with the education of our nation's children and the future promise they may hold in improving the effectiveness and efficiency of our country's educational system." One recommendation from these hearings is to establish a Presidential Commission to provide guidance for continuing federal leadership in this area.

Clearly, national interest in the potential values of computers as aids to the educative process continues to rise. What is needed to determine this potential, according to our own state-of-the-art reviews at HumRRO,[5] is a consistent framework within which to evaluate the effects of various ways of applying instructional computing. Ambiguities as to where the computer is in terms of its instructional role keep us from evaluating and exploiting its potential in a variety of applications.

In an effort to contribute to such an evaluative framework, we will try in this paper to clarify the similarities and differences in five purposes for which computers might be used to aid instruction. Each purpose implies its own method of evaluation and each has a different set of effectiveness measures that highlight its unique nature.

It is significant that the first four of these purposes involve adding new skills or knowledges to the instructional process, not merely reworking methods or approaches. When new skills or knowledge is added to a curriculum through use of a computer, a user judging the computer's worth is concerned with the value to the instruction of the additional material. This we call value-added use of the computer, and an analysis of these added values is necessary to assess achievement of the purposes.

The five purposes to be discussed have been distilled from our years of surveying developments and conducting research in academic uses of computers.[6] They are:

- Computing Opportunities—providing facilities for each school.
- Computer Literacy—learning what "computer" means.
- Curriculum Enhancement—attaining new objectives.

[1] Hamblen, 1972; Bukoski and Korotkin, 1975.
[2] Bukoski and Korotkin, 1975.
[3] Molnar, 1977.
[4] Committee on Science and Technology, June 1978.
[5] HumRRO, 1977; Seidel and Rubin, 1977; Hunter, Kastner, Rubin, and Seidel, 1975.
[6] For example, see Seidel, 1969; Seidel and Hunter, 1975; Seidel and Rubin, 1977.

- Educational Reform—obtaining a high school education at home, for example.
- Cost-Effectiveness—comparing two ways of learning English grammar, for example.

This list does not exhaust the possible categories, but we have found it useful for describing the universe of computer applications.

It may prove similarly useful for others—implementer of computer-based instruction, user, decision-maker in an educational institution—as a perspective for matching purpose of application with uniquely appropriate measures of effectiveness.

Purpose: Computing Opportunity

The "computing opportunity" purpose was succinctly stated, back in 1970, by the Presidents' Science Advisory Committee:

> In all fields where computing has been used, it has added a new dimension to education and has led the students to better comprehension of complex problems and greater insight into the meaning of quantitative expression. In these areas, undergraduates have learned through preparation of and experimentation with computer programs of the care required to define a problem logically and fully, and the assumptions needed to obtain answers to complex problems. We predict that in the future, almost all undergraduates will use computers profitably if adequate computing facilities are available.[1]

The Committee's emphasis at that time was in providing computing hardware, and we would add that providing software in a variety of forms needs to be considered as well.

We need measures of effectiveness that are unique to this purpose, that indicate an institution's commitment to the goals of computer instruction. Figure 1 shows such measures. The Computing Opportunity, first and foremost, means that users—students and faculty—must be provided access to computing facilities on site or campus, whether through a remote time-sharing capability to another campus or through local computing resources.

Purpose: Computing Opportunity

Measures of Effectiveness:

Access to Computing Facilities
A Separate Budget for Instructional Computing
Time Set Aside for Student and Instructor Use
Convenient Location(s) of Terminals
Documentation Available
Consultation Available

Figure 1

Second, willingness to establish a separate budget for instructional computing is a cogent measure of whether the institution is serious about applying computers in instruction.

[1] President's Science Advisory Committee, 1970.

One of the commonest abortive efforts to install computer instruction is an attempt to graft an instructional use onto existing administrative computing. In this case a large computer previously obtained for scheduling, payrolls, and other administrative functions is seen as a system which has a time-sharing computer-assisted instruction (CAI) capability. The would-be instructional user soon discovers, however, that the system priorities do not permit much instructional time. If the system has a time-sharing system with foreground and background partitioning, instructional computing is usually subordinated to the administrative foreground jobs. Remember, the computer center director turns out sheets of paper each day—his job is to get the budget and payroll out. So you may find students waiting with a response time on the terminal of 20 seconds, 30 seconds, a minute, and longer. Not only does time have to be set aside for student and instructor use, but a significant amount of time for faculty training is an absolute necessity for serious use of computers for instructional purposes.

Another measure, Convenient Locations of Terminals, has to do with whether, given that terminals are provided at an institution, their number, location, and state of repair, will enable people to use them. For example, I asked a Virginia English teacher whether he knew there was a CAI terminal in the school building. She did not—and it took her three days to locate it. It was in the closet in the math teacher's office. He apparently used it when he wanted to do some homework. He occasionally let his students in selected math classes use it, but it was virtually hidden from the rest of the school. Obviously, the location wasn't convenient nor had there been any attempt to put any English materials into the system. The "critical conveience level" of terminals means having enough terminals in enough locations where people can use them easily.

It also means having caretaking facilities available, particularly in the public schools. Those of us working in CAI proudly assert that the computer is a very patient tutor that will personalize the education of a student 24 hours a day. It doesn't get tired. The problem is that the janitor, the custodian, or the administrator does get tired and so do the faculty. The result is that in the public school the student may be locked out after 4:30 or 5 o'clock. Providing computing opportunity at this level of education requires the cooperation of a community. The parents, teachers, students, and administrators need to share an interest in making facilities and time available.

The other two measures of effective computing opportunity are straightforward. The right kind of documentation is required for a programmer and for the user, student or faculty, in order to make proper use of the available software. And those institutions that are making serious use of computer instruction[1] make sure that consultation is available from resource persons for the needy user.

Purpose: Computing Literacy

The purpose of computer literacy was advocated most clearly by the Mathematical Sciences Committee in Computer Education in 1972.[2] The flavor of their recommendations is presented in Figure 2. Literacy measures can be conceptualized in about three levels, although finer graduations are possible.

Essentially, at the basic level it amounts to providing awareness—what the computer means to society, what impact it can have on education. It takes the form of a course that does not require much sophistication and provides a broad introduction to understanding computers, including concepts like issues of privacy, "human obsolescense," and artificial intelligence.[3]

[1] A current HumRRO survey of exemplar institutions is described later in this paper.
[2] Seidel and Hunter, 1975.
[3] Hunter, 1978.

Purpose: Computing Literacy

Measures of Effectiveness:

Courses in

- Understanding of Computers and Impact on Society (Awareness)
- Computer Applications in Own Discipline (Knowledge)
- Computer Science and Programming (Skills)

Percent of Target Population Served

- Students
- Faculty

Achievement in Courses

Value Change Following Course

Figure 2

The second level concerns a knowledge course, in which one learns about various useful kinds of application programs, such as simulations and drill-and-practice,[1] in a particular discipline—in accounting, programs such as Pillsbury's packages; in English, remedial drill-and-practice materials in basic skills for language arts, reading, etc.; in psychology, laboratory simulations (e.g., EXPERSIM); in physics, problem-based dialogs.[2]

Lastly, literacy can refer to teaching people to become adept at program writing skills, a different kind of literacy. It involves beginning to understand what computers can do for you in a very direct way. You learn to write your own computer programs and do your own instructional development in the computer language. For example, many teachers write useful instruction in BASIC.

In any event, computing literacy is specific unto itself. It is evaluated in terms of the nature of courses provided, achievement in those courses, and percent of the target population served, whether it be faculty or students. The exemplary cases in our latest survey[3] are useful resources to contact for information related to this purpose.

Purpose: Curricular Enhancement

Using the computer to help students achieve more in a given discipline—"curricular enhancement"—is both a very common and a very important purpose.

Measuring effectiveness in this area involves choosing among several possible kinds of comparison standards. An evaluation of enhancement may yield quite different results if based on comparisons with national norms, with prior years at a particular school, with a non-computer control group, or with self-comparisons of achievement using or not using the computer. The evaluator must also decide whether to use Standard Achievement Tests or criterion-referenced tests. A more detailed set of effectiveness measures pertinent to this purpose is given in Figure 3.

[1] Kastner and Rubin, 1975.
[2] For current applications, see Seidel and Rubin, 1977.
[3] HumRRO, 1977.

Purpose: Curricular Enhancement

Measures of Effectiveness:

Time

- Average Training Time in Course
- Average Testing Time in Course
- Average Course Time

Achievement (Final Criterion Test Results)

- Accuracy or Speed Scores
- Gain Scores
- Number of Objectives Passed
- Percent Students Failed

Other Effectiveness Measures

- Student Attitudes
- Instructor Ratings
- Attrition Rates
- Absentee Rates

Figure 3

An example of ambiguities in interpreting results is provided in survey information we gathered in a category called Student Accomplishments. Much useful qualitative information and testimony suggested student improvement, but hard data are lacking.[1] About 10 Title I studies were reviewed. A major problem in trying to interpret those studies is uncertainty about what the reported numbers mean. Most of the studies seemed to show that adding 10 minutes a day of CAI (in math or reading), for 4 or 5 days a week, over the course of a school year yields greater student achievement; that is, the studies used CAI as an adjunct to the regular instruction. The findings generally showed that the students make a greater than one-month gain (in reading or math grade levels) for one month in the curriculum using CAI as an adjunct. But what does that mean? Well, the projects set achievement objectives that the students should gain at least one month or more for each month that they are using the computer. Somehow the lore in education surrounding national norm exams is that if you make one month progress for one month in a curriculum, that's what you should be doing. That's average, expected, par, and so forth.

The validity of this approach is open to question. For example, the Kansas City Title I school project compared CAI with non-CAI groups in months of achievement on a standardized, nationally normed test. The fact that it is a Title I project means the targeted student population is the disadvantaged, so, a select subpopulation is to be compared with the general population at a given grade level. This study also included curriculum revision for all students. Lastly, the researchers employed a precise experimental design (the same learners in all treatments); the students who didn't use the computer during the first semester were the students who did use it the second semester, and vice versa.

Here's the problem: Compared to the objective on a standardized nationally normed test, the students in the non-computer group showed a 1.63 (months) gain per month in

[1] See Hunter and Hargan, 1978.

their curriculum that year while the CAI group showed 1.84—a little higher average gain for one month in the curriculum. That outcome, however, is ambiguous and subject to numerous interpretations.

First, comparison of month's gains with the national norm tests does not seem to have much relevance to the local school system. Quantitative measurements from criterion-referenced tests developed within the local school system would have more meaning.

Second, it may be that what was really important was the revision of the curriculum to base it on objectives. Usually this type of revision will, in itself, lead to quite a bit of improvement.

Third, on the basis of these results the institutional decision maker has to ask whether to implement CAI. Is it worth the cost to go from 1.63 to 1.84—that is, to gain that much by adding computer technology, as opposed to revising the curriculum some other way? There are a host of questions to consider—practical, budgetary, and pedagogical.

The evaluation choices must be made within the local school system. Deciding whether to use standard, national, norm-referenced tests (e.g., the Iowa Test of Basic Skills, the SRA tests, the SATs, or the Metropolitan Achievement Tests) or locally developed instruments is part of this process. It makes sense for this to be a value-added decision and not a cost-effective decision.

In the Title I studies cited, the money was provided from external sources so cost-effectiveness can be analyzed only by future projections. When the external money is removed, the real test of cost-effectiveness occurs. Then one can determine whether and how much the school system is willing to pay for curricular enhancement. But the decision may still be based on values-added, not cost-effectiveness! Once again, consider the handicapped or disadvantaged example. The children come from a small population, the ones who are not achieving. These students could readily benefit from technology or some sort of intensive teacher augmentation. In this case the decision to adopt computer-based innovations could focus on moral and ethical issues, the values to provide help to this particular group. If, on the other hand, it is intended that the innovation pay for itself, the decision is based on cost-effectiveness. For the evaluation to be meaningful, the decision maker(s) must decide whether to focus on one or on the other.

All the studies noted above report student attitudes as positive. In fact, if a study does not report student and faculty attitudes as positive, I would be very concerned about project management.[1] The relation between attitude measures and indices of achievement is negligible unless attitudes are negative, in which case achievement would probably be less with computer-based instruction. Thus, attitudes are necessary measures, but they are not sufficient. They correlate principally with the degree of management effectiveness.

Other ways of measuring curricular enhancement have to do with jobs attained by graduates, novelty and nature of student projects, and teachers' opinions on those projects. For example, in one study at George Washington High School in Denver in the math department, the students were asked to select a project. They produced programs for several other departments and for various community organizations.[2] One student produced a carpooling program that was cited as an outstanding development by the U.S. Department of Transportation. This program has aided over 500 corporations.

[1] For example, see Misselt and Call-Himwich, 1978.
[2] Hunter, 1978.

In sum, use of the computer to enhance curricula entails choosing among a number of qualitative and quantitative effectiveness measures. A number of issues must be resolved to determine the most appropriate measures for a given institution. Is it more appropriate to compare current achievement to current-year national norms or to the previous year's local performance? Is it more relevant to compare results with a non-computer control group or for the same learner with and without computer use? Should criterion-referenced or nationally based standard achievement tests be the index of comparison? What weighting should be given to the qualitative changes in student activities and projects? These choices must be made by the responsible decision-makers (instructors, administrators, parents) according to the nature of their educational environment.

Purpose: Educational Reform

Another potential purpose for introducing instructional computing is to catalyze educational reform. Effectiveness is highlighted by the kinds of indices given in Figure 4. This purpose was given national emphasis as early as 1970 when the Commission on Instructional Technology[1] noted that formal education is not responsive enough—that educational institutions do not take into account what is known about the process of human learning, particularly the range of individual differences. The Commission advocated technology as a means to further these directions.

Purpose: Educational Reform

Measures of Effectiveness:

- Individual Student Progression
- Varieties of Learning Locations
- Changes from Credentials to Competencies
- New Approaches to Learning
- New Values

Figure 4

There are a variety of alternatives in this respect. Silber[2] has proposed an open learning system in which the whole purpose of education and computer technology is to facilitate the individual learner's contact with resources. He had in mind a huge computing system accessible throughout a community. There would be data banks of objectives that people could access through computer terminals in their homes or various other locations. His picture of an ideal learning facility was a computer terminal at home featuring color TV, with a light pen, interactive capability, and a video telephone.

Similarly, Toffler[3] and later the Carnegie Commission[4] advocated varied organizational structures in which progression was based on competency acquisition in individualized, independent settings. Courses, curricula, graduation, and objectives are translated from credentials into knowledge and skills.

[1] Commission on Instructional Technology, 1970.
[2] Silber, 1972.
[3] Toffler, 1970.
[4] Carnegie Commission on Higher Education, 1972.

New approaches to learning may also occur through use of computers in instruction, to enhance creative reasoning and the capacity for critical thinking. One dramatic attempt is Papert's embedded learning approach.[1] He placed the mathematics teaching process in a context where children of elementary school age could learn complex geometry and mathematical functions. He created a new kind of learning environment in which children of varying degrees of competence in mathematics could learn at their own pace and in their own style with the aid of a computer-driven device called a "Turtle."

> One of its key ideas is to create an environment in which interesting actions can be produced and controlled by using a mathematical language to "talk to" and to "teach" a computer. The Turtle is a computer controlled robot which will move in whatever patterns you know enough geometry to describe, and Turtle Geometry is a computer language (in our work embedded in LOGO, though it need not be) which can be used to describe movements. The wonderfully rich fact is that Turtle Geometry is at once more powerful, more accessible and more intuitive than the non-computational geometries of Euclid, Descartes, etc. I believe that this analogy is very deep: Learning math by talking to Turtles is like learning dancing by dancing with people while learning math by doing pencil and paper "sums" is like learning dancing by remote memory of pencil and paper diagrams of dancing "steps."[2]

Having initially focused on children, Papert asserts that working with such an approach can appeal to young and old alike. Computer graphics with properly designed programming can result in a common sharing of appreciation among all citizens regardless of age. And further he proposed that such means can ". . . link mathematics with aspects of beauty which already touch the aesthetic sensibilities of the non-mathematician." While Papert's dramatic claims remain to be validated, if they are accepted they can certainly add new values to society.

Clearly, the bases for deciding to pursue purposes such as those advocated by Silber, Toffler, or Papert must be rooted themselves in values. Institutions, school systems, and communities must decide the level(s) of acceptable monetary investment to achieve various types of educational reform.

Purpose: Cost-Effectiveness

I have reserved discussion of this purpose for last. Cost-effectiveness is a term that perhaps is heard more frequently than any of the other purposes listed and yet is the most misunderstood in application of computer uses to education. Figure 5 presents the dimensions relevant to measuring cost-effectiveness in an educational environment. The

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Purpose: Cost-Effectiveness

Measures:

- Student Efficiency (Achievement/Time, Money)
- Cost Avoidance
- Student Enrollment
- Attendance
- Attrition

Figure 5

[1] Seidel and Rubin, 1977.
[2] Papert, 1977.

measures themselves are relatively straightforward. What tends to be confusing is lack of clarity about what, in fact, one should be evaluating—whether, in the given situation, the use of the computer is serving a value-added purpose, such as any of those described previously, as opposed to a cost-effectiveness purpose. That is, the initial question is not what cost-effectiveness measures should be used but whether it is cost-effectiveness that should be evaluated.

Tolerable Costs or Cost-Effectiveness?

This approach to the characteristics of measurement has led me to adopt the term tolerable costs rather than cost-effectiveness when evaluating most academic computing applications. Suppose we are considering the addition of new skills, understanding, or change in curriculum. The costs of adding the potential value are either acceptable, and we pay them, or they are considered excessive for the gains anticipated, in which case we decide not to use the computer. Thus, the expenses associated with the innovation are either tolerable or not.

I define tolerable costs as the expense that an educational system is willing to bear from a given technology, or a given set of objectives attainable with new educational alternatives. Evaluation of the first four purposes, discussed earlier, is appropriately characterized in the context of tolerable costs. As indicated above, cost-effectiveness analysis is used properly with a single type of application.

The different purposes noted herein, including the difficulties in isolating cost-effectiveness applications, were highlighted in the most recent survey conducted by HumRRO. As part of a project sponsored by the National Science Foundation, we asked more than 7000 individuals to nominate institutions as outstanding examples of computing in education in the United States today. We received 370 nominees, and organized the information into usable form, published in an Academic Computing Directory.[1] We then selected 106 of these institutions as exemplary, based on completeness and accuracy of useful additional data in one or more of the following six categories:

1: Student Accomplishments
2: Institution Accomplishments
3: Spectrum of Computer Applications to Learning and Teaching
4: Computer Literacy Programs for Students, Faculty, or Community
5: Computer Science or Data Processing Curricula
6: Outreach to Community and Other Institutions

We attempted to obtain data on cost-effectiveness purposes through Category 2. This was originally labeled Cost-Effectiveness, then changed to Institutional Productivity, and finally to Institution Accomplishments. We sought data concerning:

Cost Avoidance—Curtailment of future cost increases. Example: Student enrollment in a course was doubled without adding faculty or staff. Cost thus avoided might be the estimated faculty expense for the additional students, less the cost of the computing allocated for those students. Example: Future laboratory cost increases could be avoided by using computer laboratory simulations.

Student Enrollment—Increase in student enrollment or attendance in the institution or in particular courses. Data on student enrollment and/or attendance figures before and after introduction of computing, and cost of the computing provided.

[1] HumRRO, 1977.

Student Efficiency—Student completion of courses in less time, or of more work in a fixed period of time. Data on student time, plus data on costs of achieving this efficiency.

New Services—Ability of the institution to offer new courses or programs, or services to additional student populations. Example: Remedial classes for disadvantaged.

Only 16 of the 370 institutions provided any information pertinent to this category and none provided data that could be used to determine cost-effectiveness of the computing applications. Apparently, the institutions just did not record such data, or we failed to extract it with our questionnaire, or they simply do not think in cost-effectiveness terms. It would appear that they conceive of computer use in terms of tolerable costs. The data provided by the institutions could be quantified at best as showing a marginal gain (e.g., added ease in student scheduling or test scoring) with the addition of computing facilities.[1]

When considering effectiveness analysis for any kind of purpose, we must be aware of the boundary conditions. For example, if we are dealing with cognitive, or learning-to-learn, kinds of experience, the concept of cost-effectiveness is not really applicable. Or, if new objectives are being attained by the educational alternatives or the innovation, then there is no baseline with which to make a simple cost-effectiveness comparison. Under such circumstances we have a case of a value-added application, and the next step in choosing evaluation measures is to determine whether it is to enhance a curriculum or to foster educational (system) reform.

Another boundary condition often overlooked is considering cost-effectiveness versus value-added purposes is what happens, or what would happen, to students not given the advantage of the new technology. The question is especially relevant for handicapped or disadvantaged children, who might not receive any educational benefits unless they are given alternative educational possibilities on an individual basis. The decision is probably best addressed by the cultural and moral values of our society, rather than by the numerical kind of ratio cost-effectiveness provides.

Again, one of the least known and yet most sought-for types of learning is what has been called affective learning—moral judgments, resolution of social conflict, and so on. Again, cost-effectiveness ratios are just not appropriate for dealing with this value-added type of concept.

Lastly, in dealing with costs, the economic issue of weighing today's dollars against tomorrow's dollars is frequently neglected. To do a valid cost-effectiveness analysis you need to determine the value of spending money now, for example, as opposed to spending it later, taking inflation into account. It is not legitimate to compare the cost of conventional education today with the cost of a CAI system in full use two years from now. When alternative instructional systems are being compared, what economics should apply?

Only very careful study will show whether, for your applications, you can appropriately consider cost-effectiveness of computing in education or whether, instead, you should consider values-added for a given tolerable cost.

Accomplishing a cost-effectiveness analysis requires a rigorous set of procedures.[2] Before considering these procedures, let us look at two illustrations of inappropriate cost-effectiveness analyses, one from an educational application of computers and the other from the military. The paper will conclude with a presentation of guidelines and flow diagram to aid making appropriate evaluation decisions.

[1] See Willey, 1975, for a detailed discussion of a marginal gains approach in educational computing.
[2] See, for example, Seidel and Wagner, 1977.

Common Errors of Application

Cost-effectiveness is defined herein as a purpose in which alternative means of instruction are compared relative to achieving already established objectives. The effectiveness and efficiency measures in Figure 5 must be interpreted with that purpose kept clearly in focus. There are two requirements: (a) The only variations permitted in the comparison are in the different techniques or methodologies used to reach these agreed-upon, identical instructional objectives. (b) None of the alternative educational innovations should be in any preliminary or pilot stage of development. If computer-based systems are involved, they should, at a minimum, be tested and stable prototypes.

Two kinds of errors or misapplications of cost-effectiveness are common. One type takes the form of denying the original value-added purpose for which an innovation was established, and attempting to make a cost-effectiveness comparison. The other is to compare a technique that is not fully operational against a method of education or instruction that has been thoroughly tested and has been operational for some time.

The first example is the development of a CAI system called CARE (computer-assisted remedial education), a project sponsored by the Office of Education and conducted at Pennsylvania State University.[1] The rationale for CARE was that not enough teachers were being trained to serve a moral and ethical national need. A Bureau of the Handicapped annual report for 1969 had reported that 3.7 million (62%) of the nation's handicapped children were not receiving appropriate educational services, and that some 266,000 trained persons were needed to provide such special services. The Associate Commissioner of the Office of Education, stated that programs at the time were not keeping up with the need and that, indeed, it would take 800 years with existing procedures to produce enough teachers to provide services for emotionally disturbed children.

A program was therefore designed for an alternate method for training teachers. CARE was to provide a means of instruction that would travel to the teacher or trainee, rather than have the learner go to a campus. Part of the rationale was that teachers across the nation would not give up summers or other leisure time to take the minimum required courses on a college campus, so a convenient and standardized method of instruction was needed on a national basis. Another part of the rationale was that more trained personnel would be available to work in pre-schools or day-care centers, where they could help to prevent the onset of serious learning problems in mildly disturbed children. With such objectives, the effectiveness measures should derive from the overall rationale; indeed, numbers of predicted learning problems with and without the use of the CARE training program could well be an evaluation criterion.

The CARE study came to a sad ending. The Office of Education withdrew its support in July 1976, because their analysis revealed that the student credit hours produced by the CARE system were more costly than would be the case if the participating teachers were trained on a campus. The fact that some 10,000 trained people might not have been trained at all without the mobile van concept was not considered in the evaluation, nor was the original rationale considered in the cancellation of funding. A similar decision was made internally by the Pennsylvania State University; they, too, concluded that the costs were higher than would be the case for teachers trained on campus. Unfortunately, there was a cost-effectiveness decision for a project that was explicitly initiated because of a value-added purpose—curricular enhancement to serve 3.7 million children, and to ameliorate a national need to train teachers who might otherwise not have been trained. Thus, a cost-effectiveness purpose was retroactively applied where decision should have dealt explicitly with the question: Does this innovation satisfy the moral requirement of adding teachers to the population serving handicapped children?

[1] Cartwright, 1976.

The second kind of error in cost-effectiveness analysis occurs where the purpose is appropriately cost-effectiveness, but the conditions for making an appropriate comparison do not exist. An example can be seen in a recent training application in the military[1] where CAI was found not to be cost-effective. In this study, 20 hours of instruction using CAI were compared with a similar amount of instruction in either a conventional mode or in a programmed text mode of instruction. The important point for our purposes is that the CAI system could have delivered more than 20 hours of instruction during a 16-week course (the length of the course within which the 20 hours were converted), so this short period of time alone should not have been used as the basis for evaluating the cost-effectiveness of the entire system. The CAI terminals were used 25 to 30% of the time by students, so the system was underutilized during this period. Furthermore, the course was in a prototype phase during the comparison study; that is, this was the initial application of the new version of the course of instruction being given on the computer. Moreover, if one were to extrapolate to the potential for many other courses, as well as a more complete version of the prototype course, being administered by the computer, then considerable additional savings through use of computer-aided instruction might well have been possible.

The Variables in Cost-Effectiveness Analysis

A proper, systematic approach to cost-effectiveness must take into account the following deceptively simple questions: What, why, to whom or for whom, and when? These questions translate into the following issues:

(1) To whom or for whom is the technology or technique being considered? That is, what is the nature of the target population? Who are they?

(2) Why are we considering this technology or instructional alternative? That is, what purpose will it serve? Are the same objectives going to be attained with an alternative approach, or are new objectives going to be accomplished?

(3) What is the nature of the new technology? What costs are involved, both for the new technique or method, and for the alternative(s) against which it is being compared?

(4) When is it appropriate to obtain measures of costs and of effectiveness? For example, have we allowed enough time for the full effects of the technique to become available? Different approaches to evaluating alternatives are appropriate for research versus development versus operational states. Cost-effectiveness evaluation will yield reliable and meaningful information only when the innovation is in a stable, operational state.

A number of issues are relevant in considering the above questions in operational terms. In trying to measure effectiveness, can we clearly define alternative ways to meet the same objectives? In trying to treat costs, can we account for or measure all relevant items? Can we identify all the cost dimensions for the educational alternatives being considered? Can we get agreement on the dimensions we have identified? Can we distinguish capital investment from recurring costs? Can we agree on reasonable amortization periods for our alternatives? What portions of the educational system costs can legitimately be attributed to the innovation (CAI) and what to other parts of the educational alternatives and their contribution to the resultant cost-effectiveness? The cost dimensions have to be categorized in a way that makes them comparable when relating, for example, a traditional method of instruction to a CAI alternative.

[1] Dallman, DeLeo, Main, and Gillman, 1977.

All of the above considerations must be weighed, and so must the environment in which the CAI is being tried. Do we have, for example, conditions conducive to individualized instruction? Are open education dimensions specified[1] that will encourage school and community acceptance of innovation? For example, do we have student choice of objectives, instructional self-management, a lock-step or variable schedule, competency-based time periods for mastery learning?

If we have agreement on the appropriateness of a cost-effectiveness purpose, we still have to decide whether applying the cost-effectiveness ratio is appropriate to the conditions. Most important here is to recognize when we have an operational system, technique, or technology, in contrast to one that is in a research or development status. Depending upon which point of a research-development-operational continuum has been reached, different criteria for evaluation are relevant. When an innovation is in the research stage, the proper question to ask is broadly philosophical: Is the benefit for carrying this innovation through to fruition worth the cost in resources, capital, and effort? At the very least, this means that a cost-benefit analysis is applicable to a research project, whereas cost-effectiveness evaluation applies to an operationally available alternative. Cost-benefits are defined as the societal value of an investment in a promising technique or technology, which at some future time can bring about anticipated improvements in education. On the other hand cost-effectiveness, as stated above, refers to alternative ways to meet already established objectives and requires that the alternatives being compared are operational and thus can be compared on equivalent terms.

That this process is a difficult one is illustrated by the fact that at HumRRO it took us almost two years, with the aid of experts in costing and economics, to arrive at a consistent and fairly complete set of costing categories alone.[2] Some key points to consider when analyzing cost-effectiveness follow.

First, and basic to everything else, if the comparison involves a computer-based system, both hardware and software components of the system must be stabilized. Otherwise, errors and variability will arise from unreliable equipment, undebugged software, and untried terminals and communication links. Any projected cost-effectiveness analyses done while the system is in the development phase would clearly be subject to a good deal of error from unpredictable sources.

Second, in a related way, the effectiveness of a computer-based educational system can be attributed to its instructional technology components only if the effectiveness measures are tied to those portions of the course that the technology supports. Otherwise, conclusions drawn on the cost-effectiveness of that technology will not be appropriate.

Third, cost-effectiveness of a computer-based system may also be determined from an instructional development perspective separate from delivery of instruction. It can be evaluated by its relative efficiency in aiding the development of primary and auxiliary training materials. This is acceptable, so long as the evaluation criteria are applied independent of whether the system is used for instruction. For example, many CMI (computer-managed instruction) systems could be evaluated solely in terms of their relative adequacy for developing materials, scheduling resources, recordkeeping, and similar functions. However, if the effectiveness of instruction is of primary importance, these efficiency indices should not be substituted for achievement measures.

Lastly, the appropriate use of cost-effectiveness comparisons requires fixing criteria for either cost or effectiveness. The evaluater can fix operating costs and assess the system in terms of improved instructional effectiveness, or he can fix the level of effectiveness

[1] Traub, *et al.*, 1972.
[2] Seidel and Wagner, 1977.

and assess the system in terms of the relative costs to attain that level in an operational environment. When both costs and effectiveness levels vary together, difficulties arise in determining the value of any additional benefits.

Guidance for Evaluation

The last item to be considered is the process by which one can decide when to use cost-effectiveness judgments, in contrast to value-added judgments, in comparing computers or any other innovation in instruction. Figure 6 schematically illustrates this process.

The first question to be asked, as indicated in the figure, is whether the purpose of the computer-based innovation is or is not to serve the same objectives as an alternative method already in existence. If the purposes are different, the objectives are new. In that case, the innovator or the decision-maker should judge the merits of the new opportunities provided by the innovation and, therefore, make a value-added evaluation. This would involve a "tolerable cost" decision concerning the implementation of the computer-based innovation, not cost-efffctiveness.

If the new system is to teach the same objectives as an already existing alternative, the decision-maker must determine whether the new system is in a stable, operational state. If it is not, then a cost-benefit decision must be based upon whether society's resources and priorities of available dollars permit the continued research and development of the innovation at this time. Cost-benefit decisions apply to R&D systems, and cost-effectiveness decisions apply to operational systems.

If it can be concluded that the system is in an operational stage, then the next question is whether the parameters of the model for using the system are clearly identified. Do we know, for example, how many students can be taught? Have we identified all the resources necessary to administer the innovation (e.g., carrell locations, types of terminals required, strategies to exploit instructional capacity? If the parameters are not clearly identified within the instruction model for using this computer, a pilot study should be conducted for clarification.

Once the instructional/system model is defined, the next issue is to determine that all the costs are identifiable both for the new system and for the system against which we are making a comparison. Often we can identify all the costs for CAI, yet traditional instruction costs evade even the closest scrutiny. Again, a pilot study can clarify these identifications.

Next, the implementer must decide upon an acceptable set of effectiveness criteria. This must be done in advance, so that decision-makers will know what comparisons will be made, and the technical staff responsible for implementation will record the measures that apply to those criteria. For example, are they to consider student attrition, or gains in achievement per unit of time? Are they to take into account the avoidance of future costs because of the ability to teach three times as many students with this innovation? In any event, if the criteria have not been agreed upon earlier, they should be established before the cost-effectiveness evaluation.

And lastly, of course, once these preliminary stages have been successfully traversed, a cost-effectiveness evaluation can be conducted.

This discussion sought to provide a perspective for an implementer of computer-based instruction, to guide matching a specific purpose for implementing computers in education with effectiveness measures appropriate to that purpose. If the reader is a user of an innovative system, it is hoped that this paper will clarify the nature of the innovation and prevent confusing measures across purposes. Finally, if the reader is a decision-maker thinking about implementing instructional computers, then it is my hope that the discussion will illuminate, to some degree, the various ways in which the computer can be used and benefits gained from its application in education.

A DECISION GUIDE FOR "PURPOSEFUL" EVALUATION

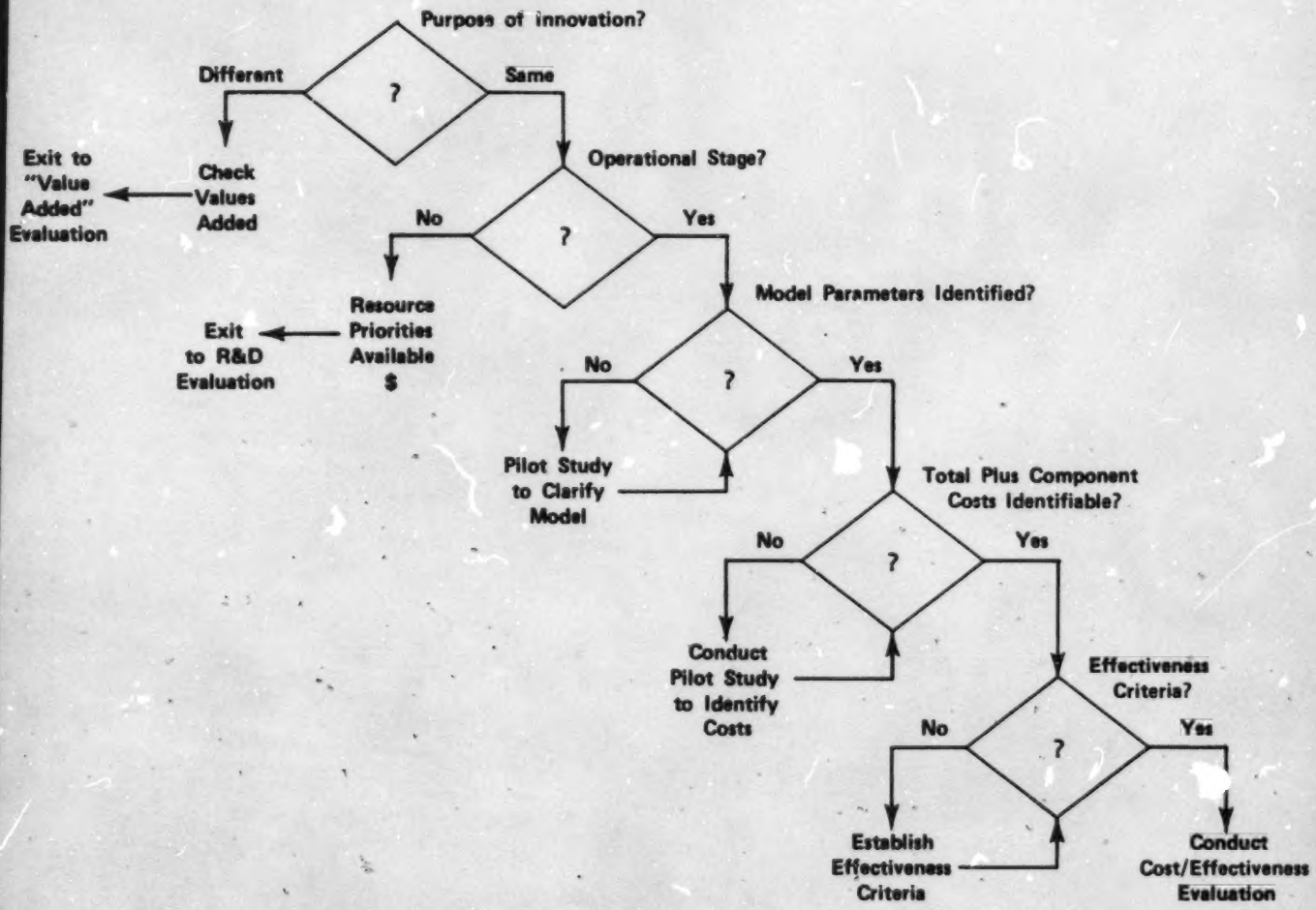

Figure 6

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